The Complexities of Shipping Liquid Cooling AI Systems: A Deep Dive

WISH CONFERENCE 2025

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Background

- Modern AI accelerators and high-compute systems generate unprecedented amounts of heat

- Traditional air cooling approaches struggle to dissipate this heat efficiently, leading to
    - Reduced ability to increase system density (rack fill)
    - System performance throttling due to thermal constraints
    - Higher risk of component failure during peak loads

Introduction

- Limitations of air cooling
  - Air is a poor conductor of heat compared to liquids
  - Increased fan speeds and airflow do not adequately address heat at high wattage
  - Energy inefficiencies rise sharply with forced-air solutions at AI-level thermal loads

- Why liquid cooling?
  - Liquid cooling enables much greater heat transfer efficiency per unit mass
  - Supports denser system deployments, faster AI model execution, and reliable hardware operation
  - Essential for next-generation data centers targeting 20+ kW per rack

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Coolant for Liquid-Cooled AI Systems

- DOWFROST™ LC25: a proprietary dielectric coolant designed for robust, safe immersion or direct liquid cooling

- Key Properties
  - High thermal efficiency
  - Superior corrosion protection for copper and other metals
  - Freeze protection down to -10°C (14°F)
  - Easy leak detection (fluorescent dye)

- Liquid-cooled AI hardware requires careful planning for shipping and handling to ensure successful deployment at data centers

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Coolant Properties and Challenges

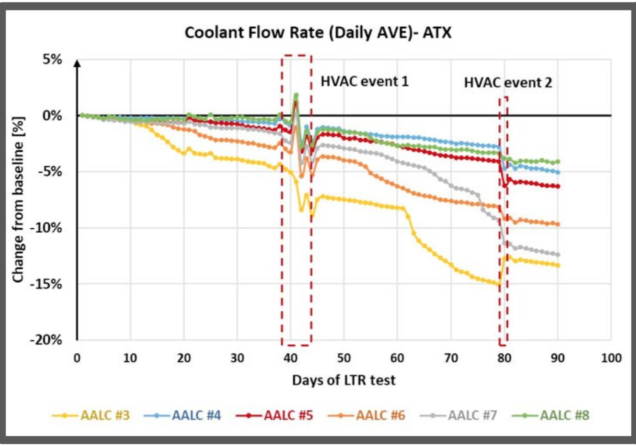
- LC25 coolant thermal expansion
  - Exposed to freezing points, expansion during phase change by volume can lead to high risk of structural damage
  - Exposed to higher temperatures, a measurable volumetric expansion volume can be calculated and considered in product design stage

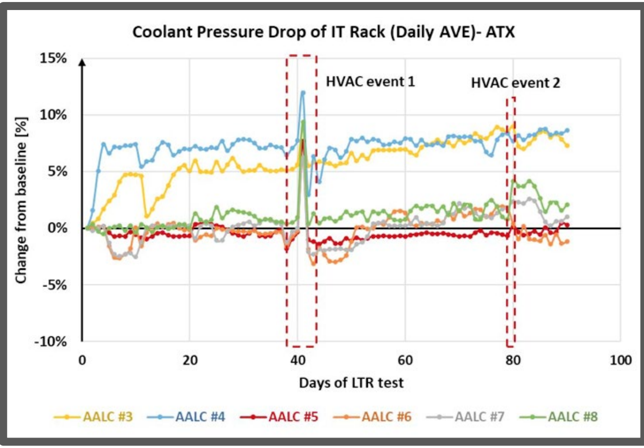
- The volume expansion may lead to following shipping risks
  - Expansion-induced stress cracking of tubing, connectors, chips
  - Component housing rupture
  - Costly leaks on arrival

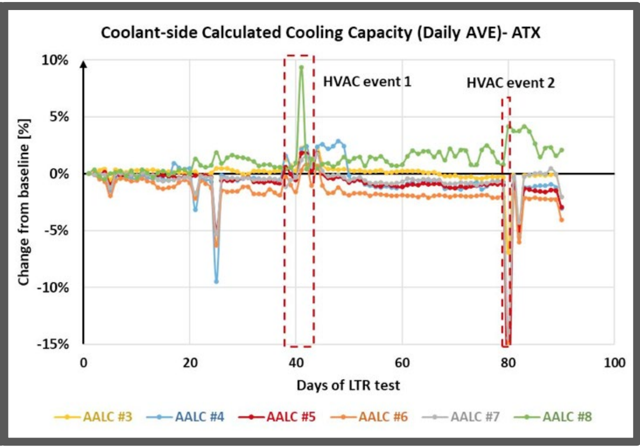
- Material compatibility
  - LC25 can react variably with different materials
    - Seals/gaskets, metals, plastics at elevated temperatures causing degradation

System Reliability Test with Coolant

- Conducted at elevated coolant temperatures (50°C) for 90 days
  - Reduced coolant flow rate
  - Increased system pressure drop (system inlet vs outlet): via cold plates and manifolds
  - Relatively stable cooling capacity: depends on coolant properties, thermal interface designs, and system architecture



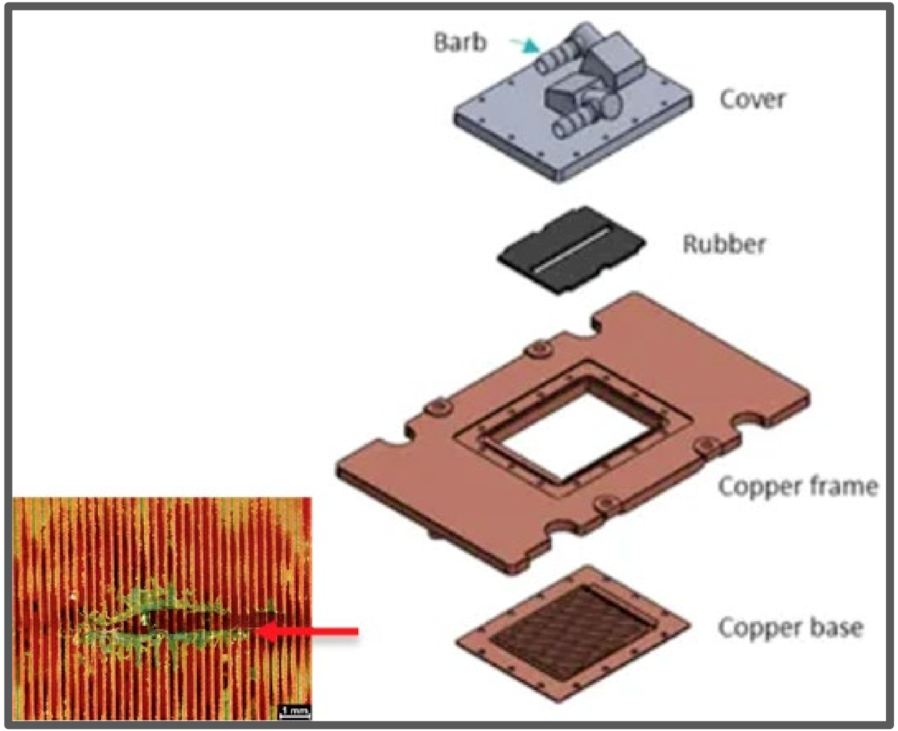




Coolant Properties Impact on Performance and Reliability

- Decreased performance
  - Decreased coolant flow rate and raised pressure drop across cold plates
  - Revealed PDMS silicone fibers on the copper surfaces
  - Swelling, leaching, and seal degradation

- Long-term, this can lead to
  - Micro-leaks
  - Corrosion risks
  - Progressive performance degradation
  - Unplanned downtime
  - Reduced system lifespan



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Shipping and Handling Methods

Method	Shipping Risk	Setup Time	Skill Requirement	Regulatory Impact	Key Operational Risks
Ship Dry	Low	High (longer fill)	High (complex fill procedure)	Minimal (no coolant in transit)	Mis-fill risk, delayed power-up, residue drying
Ship Wet	High	Minimal (plug & go)	Low (quick install)	High (coolant handling & storage - temperature management)	Freeze expansion, thermal expansion, maximum leakage
Ship Semi-Dry	Moderate	Medium (partial fill, final top-off)	Moderate (reduced fill time)	Moderate (less coolant = less regulated)	Air exposure, corrosion risk, fill error

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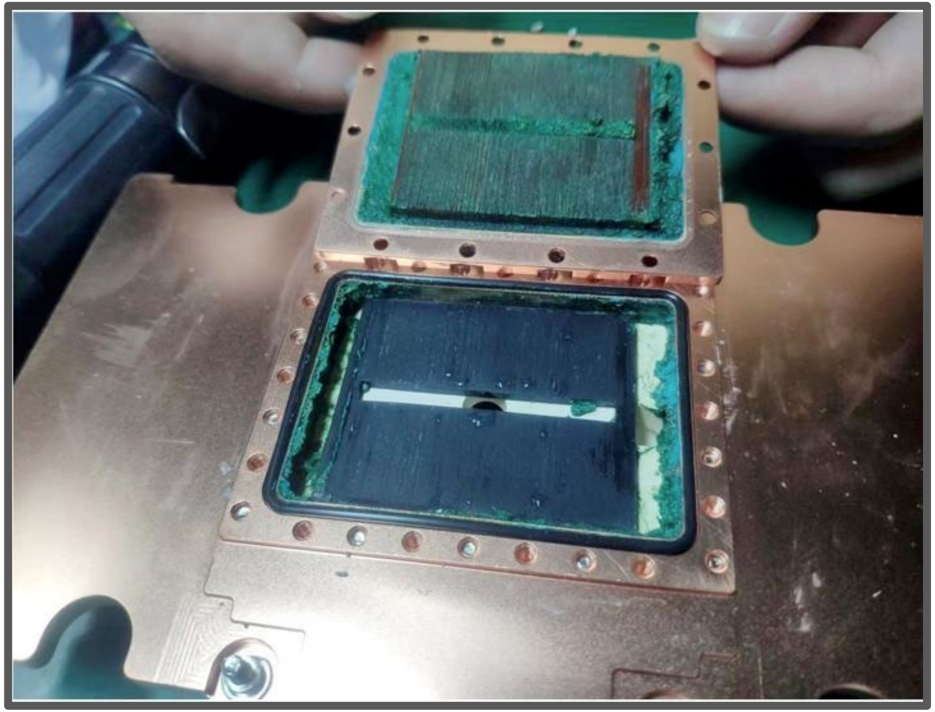
Shipping and Handling Methods Impact and Challenges

- Dry
  - Safest for global transport, requires precise filling capability and staff training
- Wet
  - Fastest deployment at destination, risk of leaks or destruction when mishandled
- Semi-dry
  - Balances transit safety and deployment speed, risk of corrosion with air exposure



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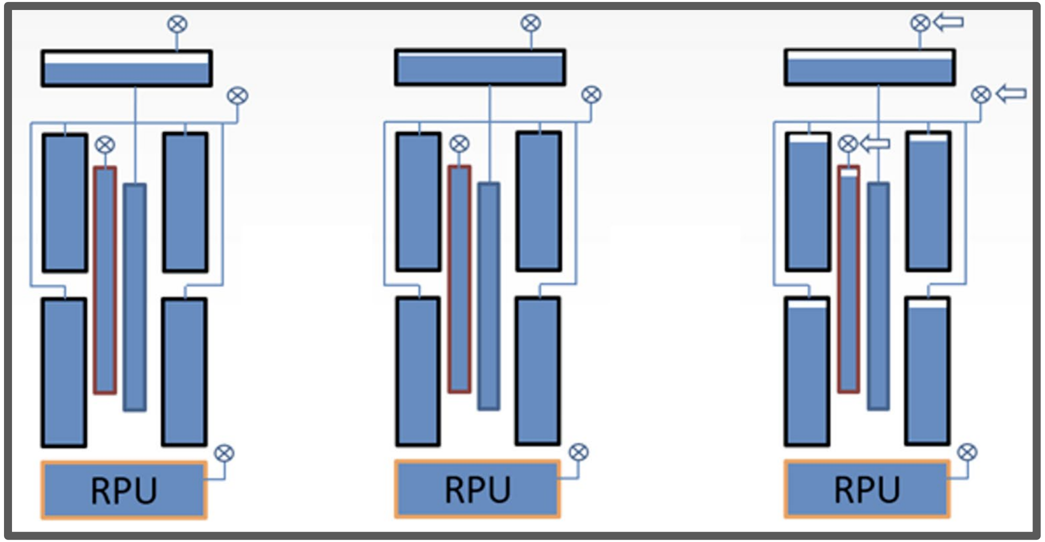
Coolant Filling Process - Minimize Air Entrainment

- Filling with external filling machine
    - Vent nitrogen charged system
    - Connect fill rig & set coolant flow
    - Unseat & reseat trays/blades
    - Create coolant closed loop
    - Use vacuum filling machine (optional)

- Filling with facility pipeline
    - Vent nitrogen charge and open-air vents
    - Flow setter & initial fill
    - Flush at nominal flow



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Conclusions

- Shipping liquid-cooled AI systems introduces unique engineering and logistical challenges
- Robust material selection is critical to prevent degradation and leakage over transport lifecycles
- Ensuring chemical compatibility between coolant (especially LC25) and system components is essential for long-term reliability
- Comprehensive reliability testing revealed risks like metal oxidation and material degradation
- Precision in assembly, process controls, and strict shipping protocols are vital to minimize failures and ensure safe delivery

Next Steps

- Deeper studies into material compatibility for new component materials
- Comprehensive 9-month Long Term Reliability (LTR) test for operational validation
  - Assess the long-term effects of LC25 on system reliability and material integrity
  - Key parameters of coolant health to be monitored include: copper inhibitor (Tolytriazole, TTZ) levels, pH, reserve alkalinity
- Address any identified compatibility issues, degradation mechanisms, or operational risks
- Continued analysis of field-shipped units to identify any process or material improvement opportunities

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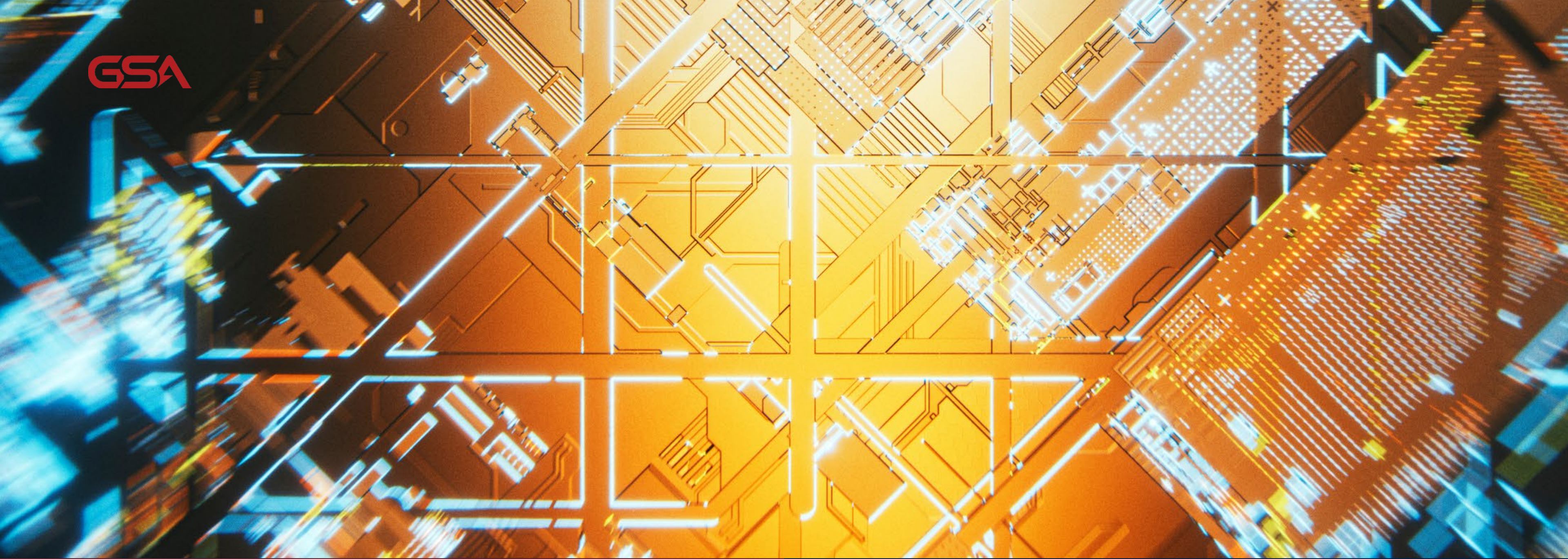

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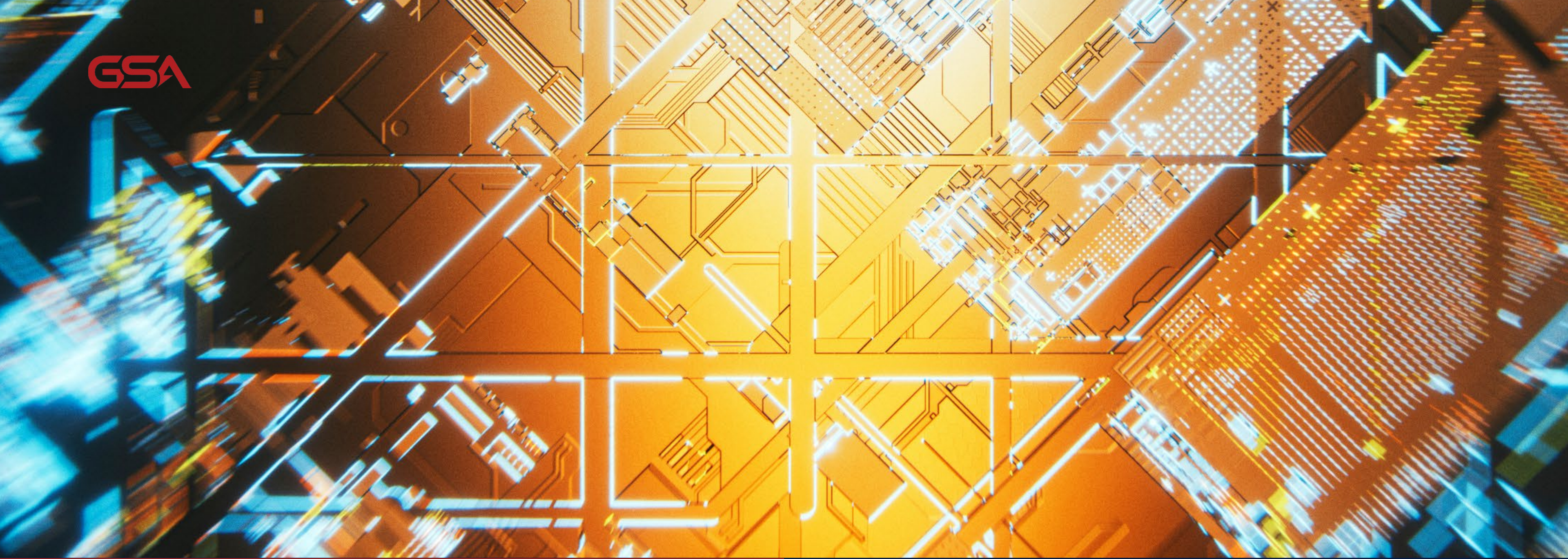

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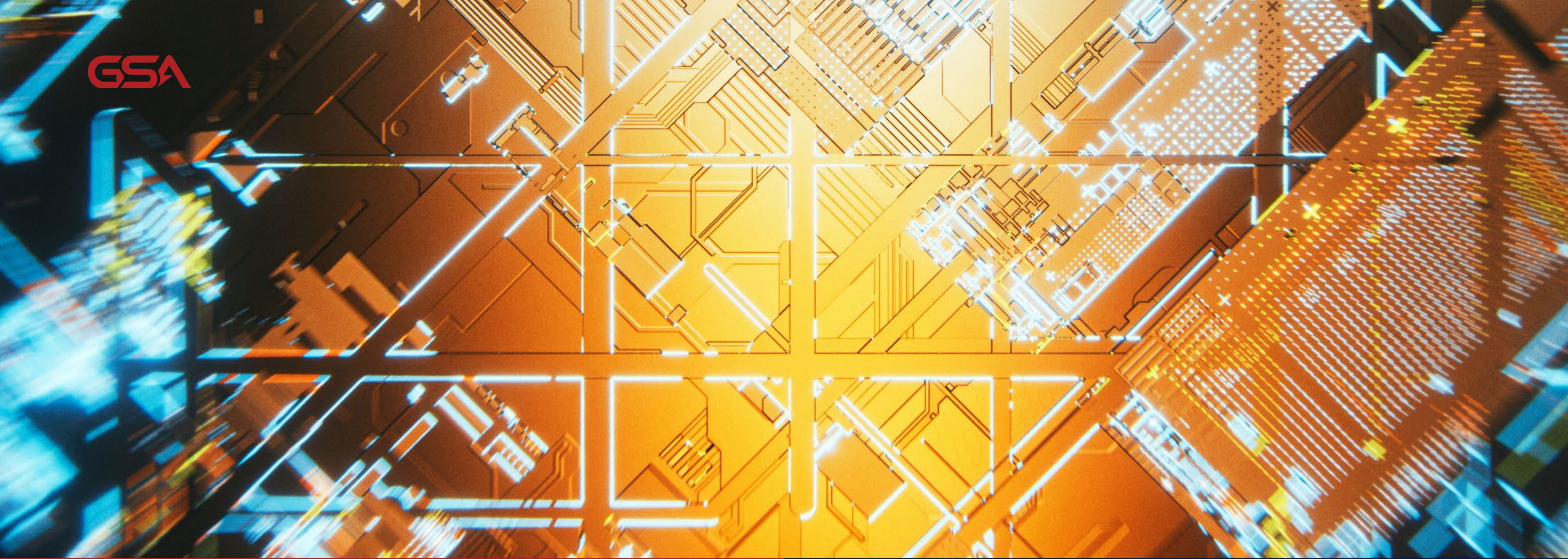

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